

V-Assembly Dual-head Efficient Resonator (VADER) for Remote Sensing Applications

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Abstract: The V-Assembly Dual-head Efficient Resonator (VADER) is a diode pumped, Nd:YAG, Q-switched, positive branch unstable resonator that employs a split laser gain module designed for optimal efficiency and thermal lensing compensation.

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The V-Assembly Dual-head Efficient Resonator (VADER) offers a tremendous advancement in efficiency and lifetime over current solid state, flight laser designs while greatly reducing system complexity and cost. Derived from NASA's HOMER laser efforts of the past decade, VADER employs a very similar cavity design using a Positive Branch Unstable Resonator (PBUR), a conductively cooled, optically optimized zigzag slab geometry, and a Gaussian Reflective Mirror (GRM) output coupler.[1] When carefully implemented, this cavity structure matches or surpasses all the benefits of a more complex MOPA system, but with 1/3-1/2 the components. When considering the extensive manpower and hardware costs associated with any flight system of similar output, this translates to a large savings in cost and schedule for the mission. VADER produces Q-Switched laser pulses typical of MOPAs with low fluence, large beam size, inherent TEM₀₀ beam quality, and symmetrical thermal lens compensation.

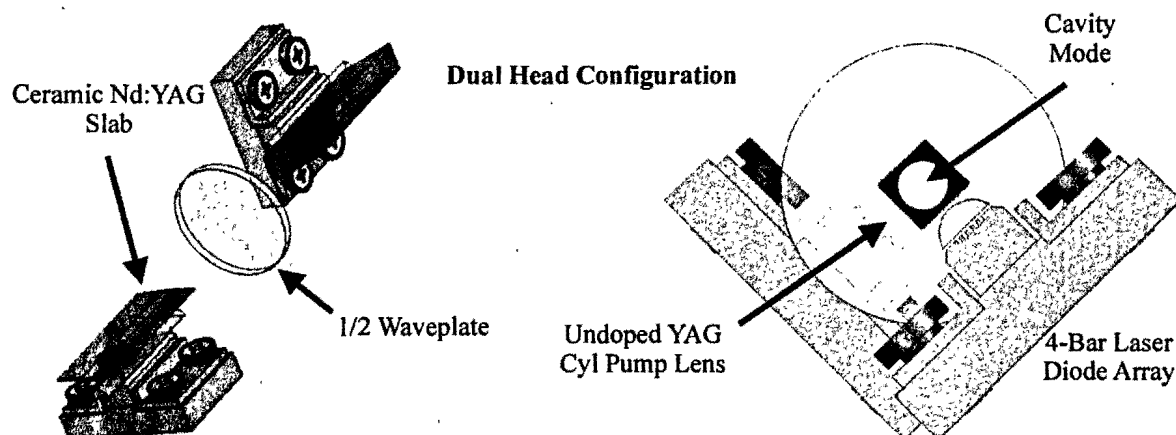


Figure 1. Isometric (left) and optic axis (right) view of the VADER laser head configuration. Excellent beam quality and high efficiency is produced in a high power, oscillator-only Nd:YAG cavity, based on side-pumped zig-zag slab gain modules.

The VADER design was based on earlier work by Armandillo et. al. proving that slab-based, oscillator-only, aperture-free slab-based cavities are capable of producing high quality, TEM₀₀ laser pulses. Furthermore, these oscillators can also produce short pulsewidths, pulse energies and even higher efficiencies than those commonly pursued with MOPA designs. The zigzag slab aspect of this effort is key for any flight system since liquid cooling, associated with rod based lasers, is a non-starter when conductive thermal control is required. Any added technologies or advances of the state of the art employed in the VADER effort is important for future LIDAR instruments NASA may pursue in the near future. Every component and technique must show a direct path to flight qualification given reasonable development funding and testing over 2-3 few years. The essential "new" components used in the VADER design are (a) the split head V-assembly gain module, (b) high power QCW diode arrays rated at 200W/bar, and (c) the use of ceramic Nd:YAG as the gain material. These individual items, concepts, and technologies may not be "new" to the laser engineering industry. However, their simultaneous use in a NASA-funded system for possible future instrument deployment is worthy of note. We are always looking for ways to reduce part count, mass, complexity and increase efficiency of any space-bound instrument. This is especially true

of solid state laser technology for remote sensing missions, given that all of NASA's solid state flight lasers to date have all exhibited wallplug efficiencies in the low single digits [4]. In VADER's case, it's 20 mJ pulse capability firmly places it in the ice and vegetation mapping altimeter class for Earth bound missions as well as future Mars mappers. Using recent flight driver electronics efficiency values, VADER's wallplug efficiency arrives readily near 10%. The part count impact is an often underappreciated aspect of such a design, as many manhours/costs are incurred to insure each optical component will survive and operate to specifications in space. These costs for each

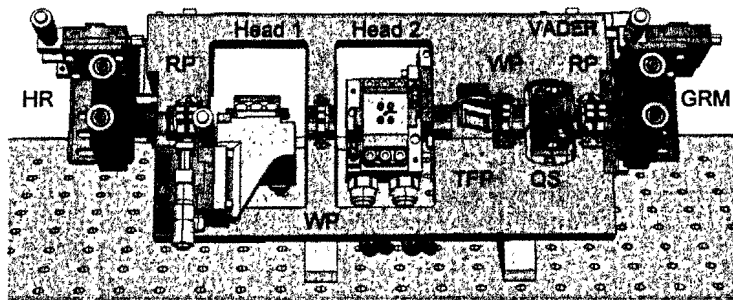


Figure 2. VADER breadboard layout. Numerous micrometer adjustment options were desired so thorough opto-mechanical studies could be performed. (RP = Risley Pair, WP = waveplate, TFP = Thin Film Polarizer.)

component include the purchase of many spares, microscopic inspections and documentation, multiple precision cleanings, clean environmental storage and transport, performance characterization, bonding processes into flight hardware, as well as random selection of spares for optical damage testing. VADER has 12 optics, including 2 risley pairs for alignment, while a typical single stage MOPA system would need at least 21 optical path components, including beam expansion, 2-pass amplification, and an extra 2 pair of risleys for post cavity alignment; essentially a part count difference of ~2X. With our earlier pulsed Nd:YAG systems employing the PBUR-GRM design, the single

zig-zag slab produced a positive thermal lens with power perpendicular to the axis of the zig-zag plane, with a weak net-negative thermal lens in the other axis [1][4]. This "cylindrical" lens increases in strength with higher repetition rates and average powers and thus, must be accounted for optically within the cavity with the addition of a negative cylinder lens within millimeters to one end of the slab. VADER's dual head geometry provides an symmetrical spherical thermal lens and is accounted for in the curvature of the nearby HR end mirror. Furthermore, subtle differences in net spectral linewidth of each pump diodes and absorption qualities in each slab will produce a slightly elliptical TEM₀₀ beams, due to unmatched thermal lensing in each axis. This beam can be spatially adjusted to maintain circular shape by tuning the drive powers in each head.

The VADER laser cavity is currently in an "adjustable" breadboard state for mechanical sensitivity analysis, but employing flight quality mounts and head assemblies. This gives us a proven means of transition to an all-flight hardware configuration for future environmental studies such as lifetesting, thermal vacuum, and vibration testing. It produces 20 mJ/pulse with each laser head employing a 4-bounce, side pumped zig-zag Ceramic:Nd:YAG slab, 2.8 mm thick and a center length of 17.0 mm. It is bonded to a MbCu heat sink to match the slab's thermal expansion and is held "over" a 4-bar diode array, rated at 200 W/bar. These arrays are back cooled G-packages, operated at 100 A and 100 us at a repetition rate of 240 Hz. The theoretical models predict best performance with our GRM and HR mirror curvatures at -2.15 mROC and -6.0 mROC, respectively. The 30 cm cavity length, the GRM's $1/e^2$ reflective spot of $\omega_0 = 1.11$ mm, and it's peak reflectivity of $R_0 = 63\%$ produces a Q-switched pulse width of ~9 ns. The cavity is held at a 45° angle about the optic axis to allow for even convective cooling for each head. Figure 2 shows the high degree of adjustment; 2 axes on each head and 5 axes for each end mirror. Eventually, the optical bench is designed to allow replacement of the gimbaled mirror mounts with flight quality bonded optic mounts to prepare the design for a transition to a miniaturized hardware design and enclosure.

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